Greenhaw

LUMBER VALUES
FOR EAST TEXAS PINE LOGS

By

G. R. Gregory and H. L. Person

CONTENTS

FIGURES

LUMBER VALUES FOR EAST TEXAS PINE LOGS

By G. R. Gregory and H. L. Person[1]
Southern Forest Experiment Station

Introduction

Progressive lumbermen know that it costs more to produce lumber from small logs than from larger logs, and that on the average the unit value of lumber produced increases with both log diameter and quality. However, measuring the difference between costs and values for logs or trees of different size or quality classes requires detailed studies of sawmill operations.

The most complete southern study of this kind was made by the Southern Forest Experiment Station in cooperation with the Crossett Lumber Company between 1935 and 1938 (4). This, like the former southern pine milling studies (1), was made at a large band mill--in which the cost of handling small logs is generally higher than at the small or medium-sized circular mill. Average log size and minimum-sized log were also greater than commonly prevail at smaller mills.

The importance of obtaining cost and return figures applicable to medium-small mills has increased greatly within the last 10 years. In 1946, for example, 45 percent of the total pine production of East Texas came from mills cutting from 1 to 10 million board feet annually. For the lower South as a whole, 55 percent of pine production is from mills of this size class--mostly single, circular-headsaw mills cutting between 20 and 40 M feet per day.

This report is intended to supplement the Crossett study. It provides information, applicable to small or medium-sized mills cutting shortleaf-loblolly pine logs, concerning the effect of log diameter and quality on:

1. Lumber grade yields;
2. Production costs--per log and per M feet of rough, green lumber;
3. Net returns from the production of rough, green lumber.

Effective use of these data requires a clear understanding of their limitations. The results were obtained from a limited log sample cut at a single, though representative, mill. They apply most directly to mills operating under similar conditions.

Wider application is possible if certain assumptions basic to this study are understood.

1. Mill costs are predicated on reasonably continuous, year-long operation. Fixed costs (fire insurance, taxes, interest, etc.) have been included with operating costs to arrive at a total cost per minute of headsaw time. These fixed costs will increase disproportionately with a decrease in operating time.

2. Costs are also based on an operating organization adjusted to a particular distribution of log sizes. Study results might not apply where differences in log size would require man-power or equipment changes.

3. The limitations of the log sample are discussed later (page 4).

In general, any radical change in methods of operation would make these findings inapplicable. The results show, however, the direction toward which both the mill operator and the grower may profitably direct their long-run efforts.

Conduct of Study

A complete record of size, quality, gross and net scale, sawing time, and lumber recovery was obtained for each study log. From these individual log records, averages could be calculated for any diameter or grade group.

Procedure

After the logs were measured, scaled, and graded in the mill yard, they were timed through the headsaw. Lumber was marked at the edger so that each board could be assigned correctly to the log from which it was cut. This marked lumber was graded on the green chain by a representative of the Southern Pine Inspection Bureau, and tallied separately for each log.

The logs were scaled by the Doyle, Scribner Decimal C, and International log rules. Standard Forest Service practice was followed in applying the last two rules. Application of the Doyle rule followed common East Texas practices: scaling diameter was taken to the nearest inch outside bark for all logs above 8 inches, and 8-inch and smaller logs were given their length as their scale.

An approximation of cubic volume was obtained separately for butt and upper logs. For upper logs, cubic volume was assumed to equal that of a cylinder having a diameter equal to the arithmetic average of the large and small end diameters of the log. Butt log cubic volume was taken as the volume of a cylinder with a diameter equal to the estimated mid-diameter. The nominal, not actual, length was taken for both upper and butt logs.

Cubic volume of lumber was obtained from the average actual thickness and width of boards (based on sample measurements) and their nominal length.

The logging cost data used in this report were adapted from the Crossett study (4). Details of this adaptation are given in the appendix, page 26.

Milling costs were based on company records for a full year's operation--from October 1, 1944, to October 1, 1945. This provided more reliable cost data than would be obtained from a short period in which costs might be distorted by unusual labor, maintenance, or seasonal conditions. For further discussion of costs, see appendix, page 31.

Lumber values are from the 1946 OPA prices for rough, green lumber.

Physical layout and operation of mill

The mill at which the study was made is fairly typical of medium-sized mills in East Texas. It cuts about 25,000 feet daily (Doyle log scale) of mixed pine and hardwood logs. The cut averages about 80 percent pine. Hardwoods were not included in the study. The mill has a 60-inch solid-tooth, circular headsaw, a 4-saw edger, 20-foot trimmer, shotgun feed, and manual setworks. Logs are turned by hand.

The 19-man mill crew was a little larger than average for mills of this type. Mills with mechanical log turners would normally have two less men on the mill deck. Some mills--particularly those which do not dip their lumber--might operate with one less than the four green chain pullers and sorters, since one man was required to straighten the lumber as it went through the dipping vat. The office and maintenance force consisted of seven men, including two company officers.

Normal cutting practices for mills of this size class were followed. A fair balance between "cutting for grade" and production speed was maintained. Small logs were generally cut into dimension stock--2 x 4's or 4 x 4's--or into one 4 x 4 in combination with any other standard size possible. While speed was stressed in cutting small logs, a definite effort was made to cut for grade on larger,

good-quality logs. In over-all efficiency, this mill is probably
above the East Texas average.

The log sample

Selection of logs.--Logs were obtained from two national for-
est sale areas and from three private tracts. The logs were taken as
they came from the log deck, selection being exercised only to secure
the planned grade and diameter distribution. Plans called for about
30 logs of each log grade
(see page 5 for log grades
used) in each 2-inch diam-
eter class. Some of the
upper diameter and grade
classes were never com-
pletely filled (table 1)
because of a scarcity of
logs in these classes.

The log sample stud-
ied does not represent ei-
ther an average woods or
mill run of logs. The study
data are weighted in favor
of grade 1 logs and logs of
large diameter. This inval-
idates "average values" that
might be calculated by com-
bining data from the various
diameter or grade groups.
Where grade or diameter had
no significant effect on a
particular item, averages
are perfectly valid and are
presented in this report.

Table 1.--Distribution of log sample

Diameter class (inches)	Grade 1	Grade 2	Grade 3	All grades
	- -	Number	of logs	- -
6	(1/)	(2/) ·	29	29
8	(1/)	30	31	61
10	16	35	36	87
12	19	31	35	85
14	17	34	32	83
16	12	18	25	55
18	8	9	14	31
20	2	5	7	14
22	0	1	5	6
24	0	0	2	2
28	0	1	0	1
Total	74	164	216	454

1/ Minimum diameter of grade 1 logs is
10 inches.
2/ Minimum diameter of grade 2 logs is
8 inches.

The study was designed to determine log values by log diameter
and grade, and it is believed that the values given may properly be ap-
plied to most East Texas pine stands once the distribution of logs by
diameter and grade has been determined.

Description of log sample

Shortleaf pine made up about 78 percent of the total sample and
loblolly the remainder. Distribution of the two species was fairly
uniform by grades, but there was more loblolly in the larger diameters.
For the whole group, the ratio of shortleaf to loblolly is probably
close to the natural distribution of these species in this region of
East Texas. At any rate, the effect of species on lumber value is
probably small. The Crossett study showed only a slight difference

(favoring shortleaf) in grade return between the two species, and in actual mill practice no distinction is made between them.

The proportion of butt logs was high in grade 1 and grade 2 and low in grade 3 (table 2). But this follows naturally from the application of the grade rules. Log grade usually, and log diameter always, decreases from the butt to the top of a tree, so that most grade 3 logs under 12 inches were from upper cuts.

Distribution of log lengths by diameter classes was reasonably uniform, and probably representative of the lengths to be found in mill-run East Texas pine logs. Sixteen-foot logs made up 72 percent of the total log sample. The average length in the different diameters and grades ranged from 15.7 to 17.3 feet. It is recognized that length is important when considering such facts as lumber yield and lumber value, and the data in this report should not be applied directly to a mill whose average log length is considerably more or less than 16 feet. For most East Texas mills, however, no correction for length should be necessary.

Table 2.--Distribution of log sample by log grade and position in tree

Grade	Butt	Middle	Top	Unknown	Total
		- - Percent of log sample - -			
1	89	11	0	0	100
2	69	20	2	9	100
3	35	21	12	32	100
All grades	56	19	6	19	100

Log grades

The basic log grading rules used were those developed by Reynolds at Crossett (see appendix, page 25). Two modifications of the Crossett system were made. Logs under 8 inches in diameter, excluded under the Crossett system, were included in this study. Grade 4 logs, which are essentially culls, were excluded. The grading rules as applied are as follows:

No. 1: Surface-clear logs 10 inches or over in diameter inside bark at small end, and logs over 16 inches d.i.b. with not more than three 2- to 4-inch knots; length, 10 feet or over.

No. 2: Logs 8 inches d.i.b. or over containing numerous small knots; or logs more than 14 inches d.i.b. containing four to six 2- to 4-inch knots; length, 10 feet or over.

No. 3: Knotty or crooked merchantable logs that do not fall in either No. 1 or No. 2 grade; length, 10 feet or over.

The Crossett rules, among several available, were chosen because they are easily applied, are relatively well known, and at Crossett proved reasonably accurate. Their use also facilitates comparisons between the current study and the Crossett study.

Results

Lumber recovery,
overrun, and waste

Lumber recovery by log size and grade.--The actual amount of lumber cut from a log will differ considerably among mills. Mill efficiency, the type of equipment used, the thicknesses cut, and other factors contribute to this variability. Allowance for surfacing also varies at circular mills. The recovery shown here (figure 1) illustrates the effect of log diameter on lumber yield under conditions prevailing at the mill studied. Differences in lumber yield among the three log grades were insignificant.
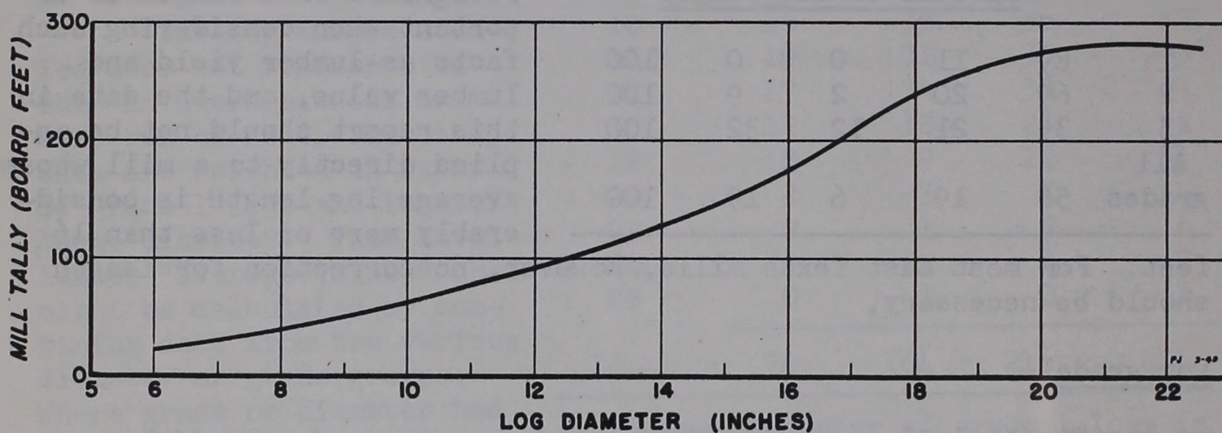

Figure 1.--Lumber production per log.

The lumber recovery curve (figure 1) begins to flatten out between 18 and 19 inches because logs above this diameter were simply too large to be handled efficiently at this mill. The point at which this occurs will vary among mills. Use of larger headsaws, a top saw, or "steam niggers"--or similar differences in equipment--would tend to move this point to a higher diameter. Use of lighter equipment would shift it to a smaller diameter. This should be borne in mind when applying the data to other mills.

Effect of log diameter and grade on overrun.--Overrun[2] from a log of a given size is affected by variations in application of the

_____

2/ "Overrun" or "gain" is the excess of mill tally over log scale. "Underrun" is its opposite--the excess of log scale over mill tally. Though overrun can be expressed equally well in board feet, in this report the more usual practice of expressing it as a percent of the log scale concerned is followed. Only "rough green" mill tally is considered in this report.

log rule being considered and conditions influencing net lumber recovery. The more important of the factors that increase overrun are:

1. Reducing saw kerf;

2. Cutting thicker materials--e.g., 2-inch instead of 1-inch boards;

3. Cutting scant thicknesses;

4. Recovery of lumber grades which admit unsound material;

5. Utilization of narrow widths or short lengths from the swell or taper of the log;

6. Exceptional skill on the part of the sawyer;

7. Cutting for quantity rather than grade.

As these factors vary from mill to mill, so will the overrun under any log scale vary. The particular conditions existing at the study mill and their effect on overrun are discussed in the appendix, page 27.

For easy comparison, the overrun of the three log rules as they are most commonly applied (Doyle gross, and Scribner Decimal C and International $\frac{1}{4}$-inch net[3]/) is given in figure 2.

The Doyle rule gave by far the greatest overrun in small logs--104 percent at 8 inches. This dropped rapidly, however, crossed the curve of Scribner overrun between 13 and 14 inches, and at about 20 inches became underrun. Because of the scaling practices followed for small logs, the Doyle overrun dropped rapidly for logs under 8 inches. Though the overrun from this rule is high, it would have been very much higher still if logs had been scaled inside bark (as for Scribner and International) and if log length had not been substituted for actual scale for logs below 8 inches in diameter.

Scribner Decimal C scale gave highest overrun at 8 inches and within the limits of the diameters studied gave no underrun. From its maximum at 8 inches (47 percent) overrun dropped rapidly to 25 percent at 11 inches, then continued a more gradual decline. The values in the Scribner Decimal C scale are rounded off to the nearest 10 feet for ease in recording and calculating. Over a large number of logs with average diameter range, the errors induced by this rounding average out, but for the smaller diameters they introduce a big variation in overrun. For example, 7- and 8-inch logs both scale 30 feet, yet the 8-inch log will yield much more lumber.

_____

3/ Gross log scale is the total scale of the log. Net log scale is the gross log scale less the deductions made for defect (rot, sweep, splits, etc.).
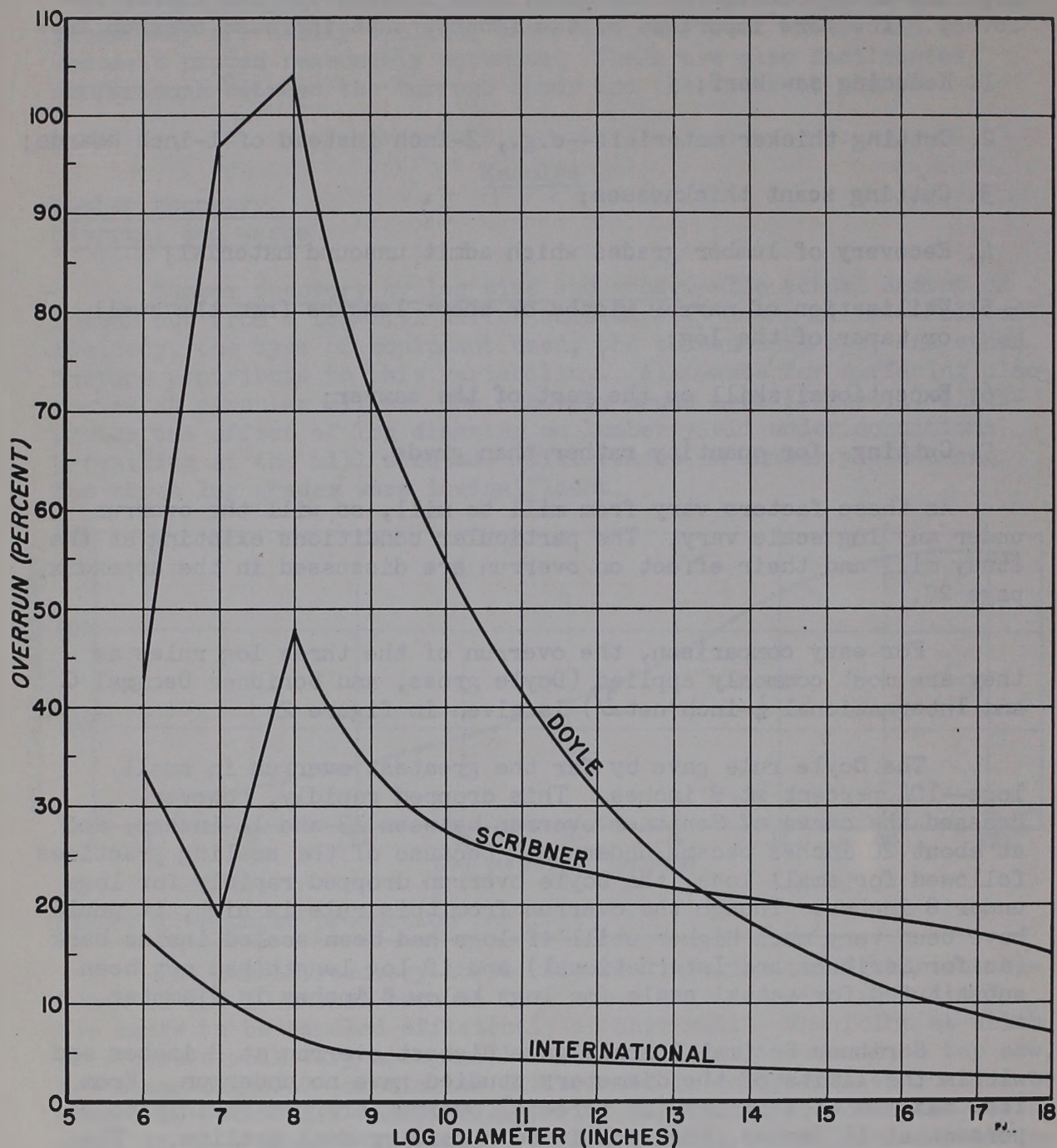
Figure 2.—Overrun: Doyle, Scribner Decimal C, and International ¼-inch log rules (Scribner and International net scale).

Overrun values from the International ¼-inch rule were by far the most consistent and were close to mill tally. The smallest logs (6-inch) did overrun 17 percent, but this dropped to only 5 percent at 9 inches and declined steadily to 2 percent at 20 inches.

A comparison between the overrun from gross and net log scales of both Scribner and International ¼-inch rules showed only a slightly greater deduction for defect under the Scribner than

under the International. Overrun on gross International scale, how-
ever, was less than zero from 9 inches and up, while overrun with
gross Scribner fell to zero above 21 inches. Because of the small
amount of defect (about 4 percent of gross log scale) and the fairly
uniform distribution of defect by diameters, no separate analysis of
the effect of defect on yields and values was considered necessary.

The ratio of cubic-foot recovery to total cubic log volume
(figure 3) increased with increasing log diameter from only 54 per-
cent at 6 inches to a maximum of 73 percent at 18 inches. Beyond
this diameter, cubic-foot recovery fell off to less than 70 percent
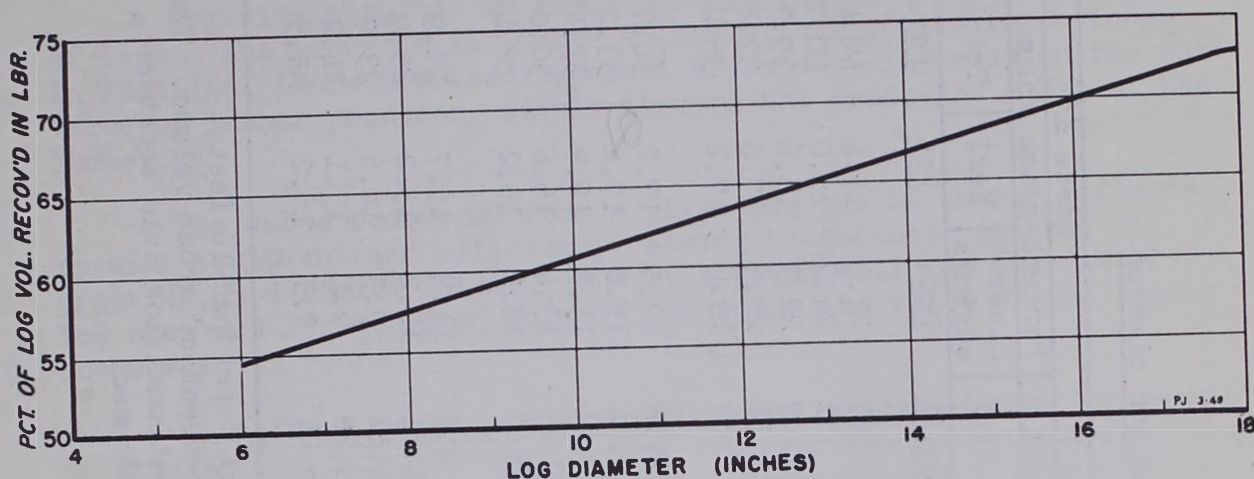at 22 inches because of excessive waste in sawing.

Figure 3.--Cubic-foot volume of lumber in percent of total cubic-
foot log volume.

Waste.--Analysis of the records of total cubic content of
study logs and of lumber recovered provided a basis for estimation
of log volume wasted[4] in the manufacture of rough, green lumber
(table 3).

The ratio of slabs and edgings to sawdust was calculated from
the International log rule equations. A 5/16-inch kerf was assumed
in these calculations. This method of determining kerf waste assumes
cutting of 1-inch boards only, and makes no allowance for the wany-
edged lumber frequently cut from small logs. Errors introduced by
both causes are largest in the small diameter classes.

The conversion factor of 96 cubic feet per M feet of lumber was
calculated from green chain measurements of thicknesses and widths.

[4] Waste as used here means all wood other than lumber. It is
recognized that much of this volume is actually used by many mills
for fuel, moldings, etc.

Table 3.--Lumber recovery and waste by diameter classes

Diameter class (ins.)	Cubic [1] volume per 16-ft. log	Utilized as lumber		Waste [2]							
		Per 16-ft. log	Portion of gross vol.	Per log		Percent gross volume			Per M b.m. lumber tally		
				Slabs & edgings	Kerf	Slabs & edgings	Kerf	Total	Slabs & edgings	Kerf	Total
	Cu.ft.	Cu.ft.	Pct.	Cu.ft.	Cu.ft.	Pct.	Pct.	Pct.	Cu.ft.	Cu.ft.	Cu.ft.
6	4.36	2.37	54.4	1.18	0.67	27.0	15.4	42.4	47.75	27.21	74.96
7	5.67	3.17	55.9	1.40	.91	24.7	16.0	40.7	42.39	27.68	70.07
8	7.15	4.10	57.3	1.62	1.19	22.7	16.6	39.3	37.87	27.86	65.73
9	8.82	5.20	59.0	1.83	1.50	20.8	17.0	37.8	33.71	27.63	61.34
10	10.64	6.44	60.5	2.02	1.83	19.0	17.2	36.2	30.18	27.26	57.44
11	12.66	7.85	62.0	2.21	2.18	17.5	17.2	34.7	27.04	26.69	53.73
12	14.83	9.42	63.5	2.38	2.54	16.0	17.2	33.2	24.25	25.94	50.19
13	17.19	11.19	65.1	2.52	2.91	14.7	16.9	31.6	21.63	24.97	46.60
14	19.72	13.15	66.7	2.64	3.27	13.4	16.6	30.0	19.30	23.88	43.18
15	22.42	15.32	68.3	2.74	3.63	12.2	16.2	28.4	17.20	22.72	39.92
16	25.30	17.66	69.8	2.83	3.98	11.2	15.7	26.9	15.38	21.62	37.00
17	28.36	20.22	71.3	2.89	4.31	10.2	15.2	25.4	13.74	20.46	34.20
18	31.58	22.99	72.8	2.93	4.62	9.3	14.6	23.9	12.25	19.27	31.52
19	34.99	25.37	72.5	3.19	5.28	9.1	15.1	24.2	12.06	19.98	32.04
20	38.57	27.46	71.2	3.59	6.24	9.3	16.2	25.5	12.55	21.83	34.38

[1] By Smalian's formula, allowing 2 inches of taper per 16 feet.
[2] Exclusive of defect, which averaged 3.3 percent of gross volume. The ratio of kerf to slabs and edgings was determined from International log rule equations, with kerf allowance of 5/16 inch, and 1-inch lumber production assumed.

Lumber grades and values

It is generally recognized that log quality directly affects lumber recovery values. Grading standards, such as those embodied in the Crossett rules, have been developed to evaluate this quality factor. But in spite of their demonstrated value in the classification of logs, they are seldom used in the South. As a shift from a seller's to a buyer's market occurs, however, log quality will receive increasing attention; and log grades which provide a reasonably accurate measure of log quality should find increasing acceptance among progressive timber growers and sawmill operators.

Log size also has an important bearing on the recovery value of logs. The increase in lumber volume with log size is obvious. In addition, there are less apparent effects of log size on the unit value of lumber produced, mainly through the grade and width of the lumber.

The value recovered from a given log is, of course, affected by mill equipment and efficiency, sawing techniques, general mill practice, and similar items. But at a given mill the two factors, log size and log quality, largely determine the value of the lumber produced.

The effect of log diameter on lumber grade.--Lumber grade was related to log size because, on the average, the lumber cut from the larger logs had a higher proportion of clear material. This relationship would hold for a group of logs, even though not classified by grade5/. Most significant was the effect of diameter within grade 1 logs (figure 4). The percentage of combined C and B and Better increased rapidly in the smaller diameters, and continued to increase moderately in grade 1 logs. No constant trend was evident in the larger diameters of log grades 2 and 3.

The proportions of dense grades did not follow the above pattern. In both log grades 1 and 2, the proportion of dense material decreased from over 40 percent of total log volume at 10 and 8 inches respectively, to about 20 percent at 14 inches. Though little dense material was cut from grade 3 logs, even here the proportion decreased with increasing diameter.

This is believed explained by the not unusual cutting practices of the mill. Small logs (6 to 10 inches) were usually cut into dimension and structural materials, and so are graded under density classifications rather than finish. But in sawing larger logs, the high-quality, high-value finish grades are cut from the outside of the log.

5/ It was not possible from this study to determine the effect of log diameter on lumber grade recovery independent of log grade.
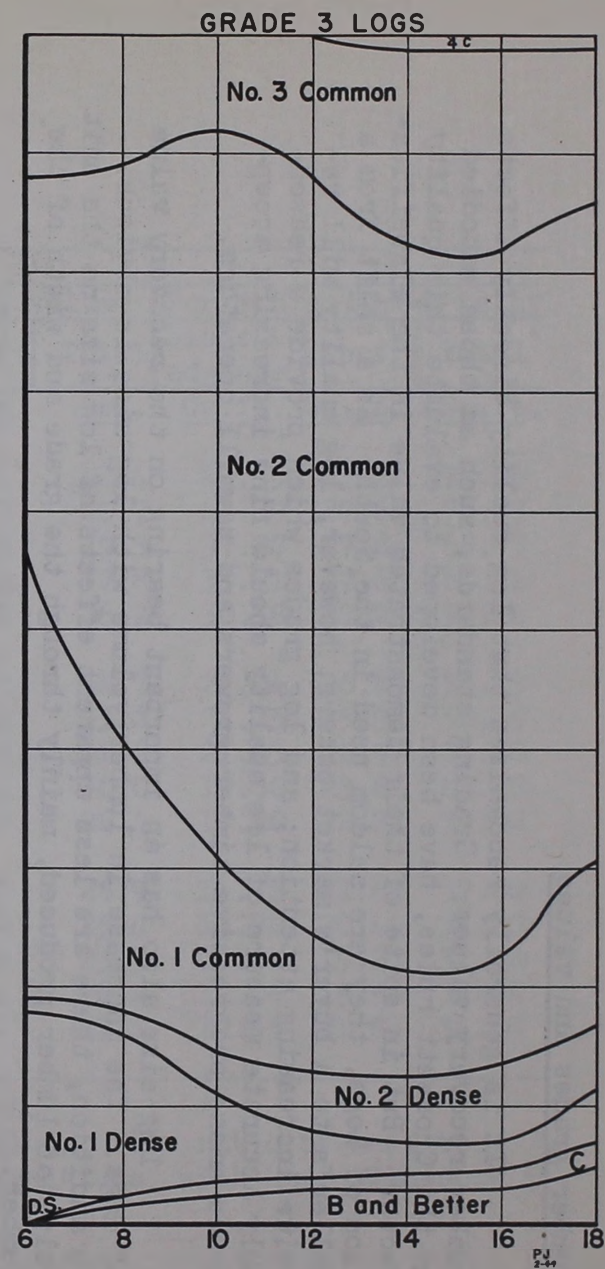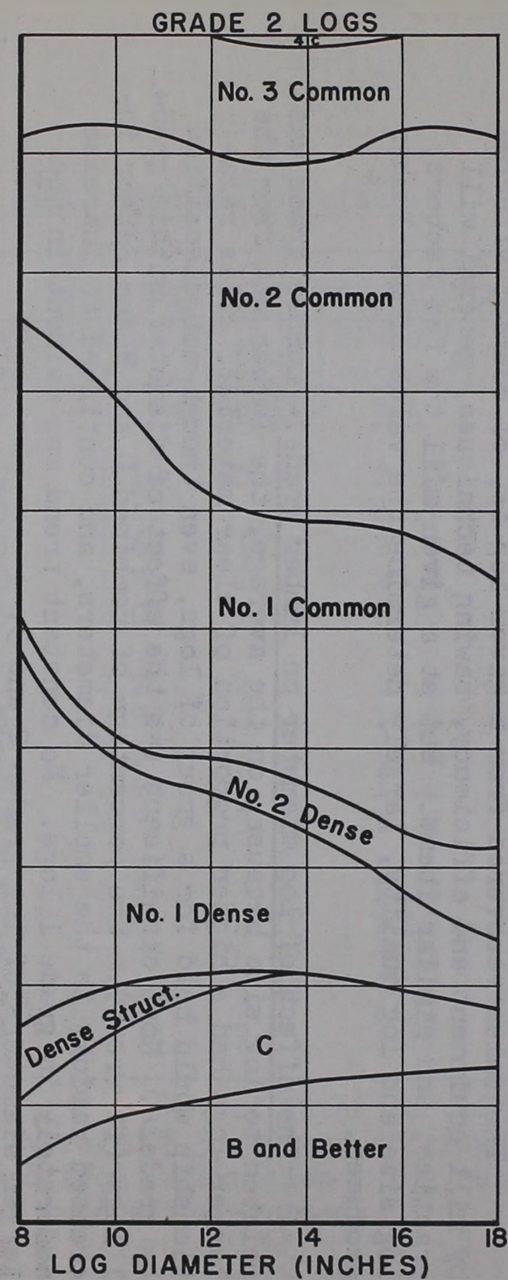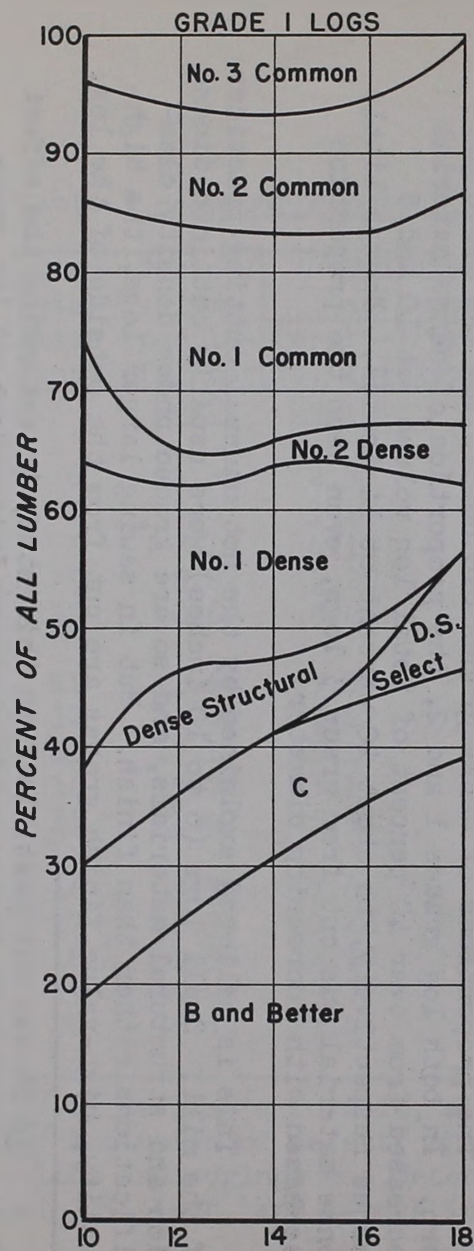
Figure 4.--Lumber grade recovery from grade 1, 2, and 3 logs.

Much of the interior portion will not produce structural material, so is cut into commons. The gradual decline in dense grade as diameter increases, and the corresponding increase of finish grades, is the result. Similar effects have been observed in other studies (3, 4).

The effect of log grade on lumber grade.--The effect of log grade on lumber grade recovery is readily apparent from figure 4. In percent of total lumber, the average yield of finish grades from 16-inch logs,

Log size and lumber grade	Log grade 1	Log grade 2	Log grade 3
	- - Percent - -		
10-inch logs:			
No. 1 Common and above	86	69	31
No. 2 Common and below	14	31	69
16-inch logs:			
No. 1 Common and above	83	58	23
No. 2 Common and below	17	42	77

for example, was 44 percent for grade 1, 20 percent for grade 2, and only 5 percent for grade 3 logs. If all the lumber were divided into just two grade groups-- No. 1 Common and above and No. 2 Common and below--then the yield from 10- and 16-inch logs would be as shown above.

Lumber values.--The differences found in lumber grade yields are sharply reflected in the lumber values of various log grade-diameter groups.

Table 4.--Lumber value per log

Log diameter (inches)	Grade 1	Grade 2	Grade 3
	- - Dollars - -		
6	...	...	0.85
7	...	...	1.15
8	...	1.61	1.48
9	...	2.03	1.85
10	2.81	2.57	2.33
11	3.48	3.16	2.85
12	4.24	3.83	3.41
13	5.13	4.60	4.08
14	6.17	5.49	4.86
15	7.42	6.51	5.84
16	8.86	7.67	6.96
17	10.69	9.14	8.36
18	12.53	10.54	9.71

Lumber values per log by diameter and log grade are shown in table 4. Grade 1 logs varied in lumber value from $2.81 for 10-inch logs to $12.53 for 18-inch logs. Grade 2 values rose from $1.61 at 8 inches to $10.54 at 18 inches. Grade 3 values rose from $0.85 at 6 inches to $9.71 at 18 inches.

Most of this increase in value with diameter was due to increase in volume. A part, however, resulted from an increase in the proportion of higher lumber grades recovered and from the wider widths produced from the larger logs. Almost $8 of the $8.93 increase from 8-inch to 18-inch grade 2 logs, for example, stems from the increase in volume; the rest of the increase is from the rise in value per M.

Average values per M feet of lumber produced further demon-
strated the effect of log grade (figure 5). The three grades re-
sponded differently to increasing diameter--lumber from grade 2 and
3 logs increased only slightly in value per M, while grade 1 logs
showed a substantial and more constant increase. Lumber from 10-
inch grade 1 logs was worth $44.65 per M; from 10-inch grade 2 logs,
$40.78; and from 10-inch grade 3 logs, $37.00. Lumber values per M
from 18-inch logs showed a greater total spread--being $52.65,
$44.30, and $40.80 for grades 1, 2, and 3, respectively.

Throughout this section on lumber grade yields and values,
the data have been given in terms of log grades. A statistical
check showed that in 19 times out of 20 a buyer purchasing a group
of 400 or more logs could, by following these grading rules, pre-
dict the value per M board feet of the lumber to be produced with
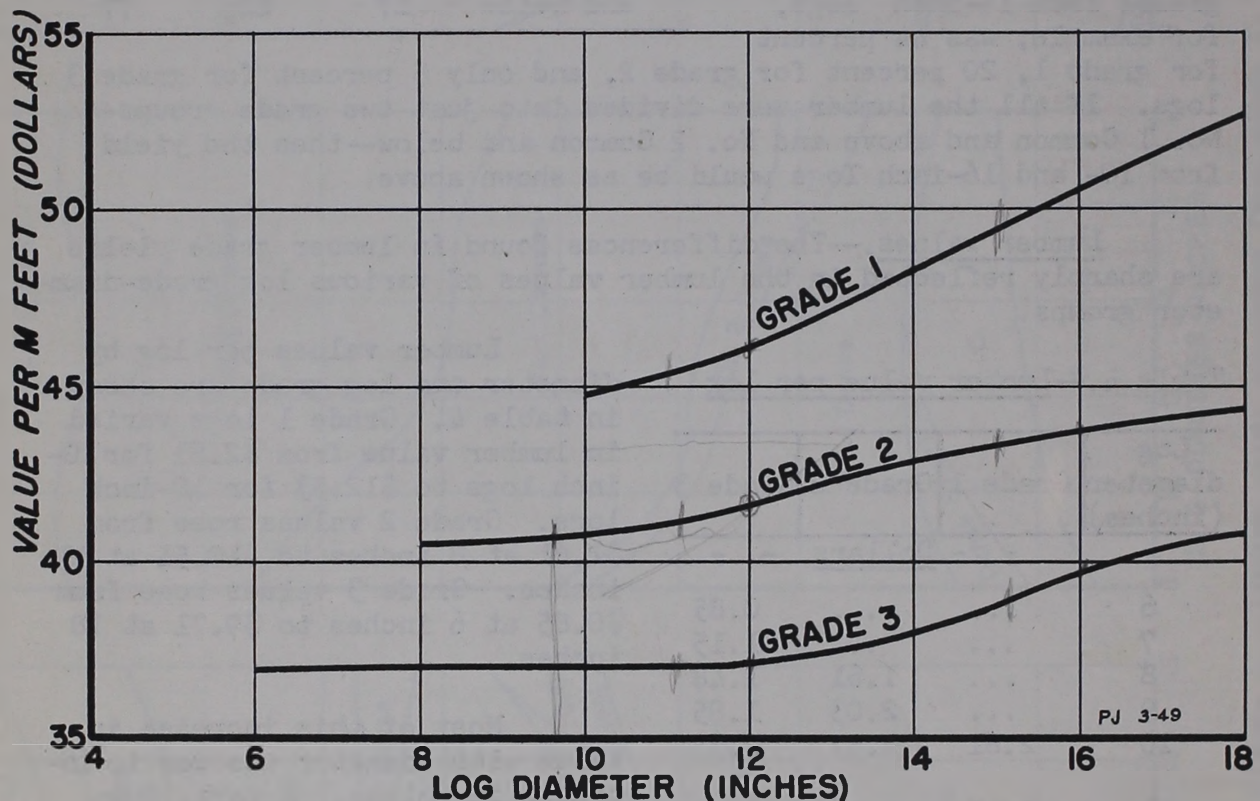an error of less than 5 percent.

Figure 5.--Value of lumber recovered from logs of different grades.

Cost of production

To determine the per M cost of production by diameter classes,
all costs were combined and a total cost per minute of headsaw time
was calculated. Determination of the cost of milling any log or
group of logs then became a matter of finding the time required to
saw them.

To determine the per-minute cost of mill operation, all ex-
penses incurred (see appendix, page 31) between October 1944 and

October 1945 were summed to give a total operating cost for the year. By taking costs over this long a period, the effects of any unusual expenses were minimized and most normal and seasonal fluctuations were included. The total operating time for this same period was next determined, and reduced by the delay percentage[6]/calculated from study data. The total operating cost ($52,916.82) was then divided by the net operating time (2,087.22 hours) to give a net per-hour cost of $25.35, or a per-minute cost of $0.42255. This per-minute cost, when multiplied by the net sawing time in minutes, gave milling cost per log.

All milling costs were prorated according to headsaw time. The headsaw sets the pace for the entire mill, for as headsaw production decreases, men and machines throughout the mill must decrease their production. Their cost, however, remains essentially the same and must be charged against a smaller output.

Production costs and sawing time.--Though influenced by other factors, sawing time and cost are closely related to log volume (figure 6). Sawing time per M feet of lumber (figure 7) decreased from 23 minutes[7]/ (cost $9.65) for 6-inch logs to $12\frac{1}{2}$ minutes (cost $5.28) for 18-inch logs. Beyond this point, unit cost and time increased rapidly. Most logs over 18 inches in diameter were just too large to be handled efficiently by the mill. The one 28-inch log included in the study took 53 minutes to saw. The log size handled at maximum mill efficiency (lowest cost per M) was about $18\frac{1}{2}$ inches.

There was no significant difference in time or costs between logs of different grades.

Cost index.--To facilitate application of these findings to other mills like the one studied but having a different average log size, an "index of sawing costs" is given in table 5. Since the Doyle index is based on the overrun at the study mill, it will not give absolutely correct results for a mill having a different overrun or for one applying the Doyle rule in a different fashion. It does, however, provide a basis for determining sawing costs with reasonable accuracy.

To use this table, an operator must know the average diameter of the logs he cuts and the average sawing cost per M. Most operators will know the approximate average log diameter, but will probably have to calculate average sawing cost by dividing annual mill cost by the annual cut of the mill--either mill tally or Doyle log scale.

---

[6]/ During the study, delay time (saw changes, equipment breakdowns, rest periods, etc.) amounted to 13.68 percent of the total operating time. For a complete discussion of delay time, see appendix, page 30.

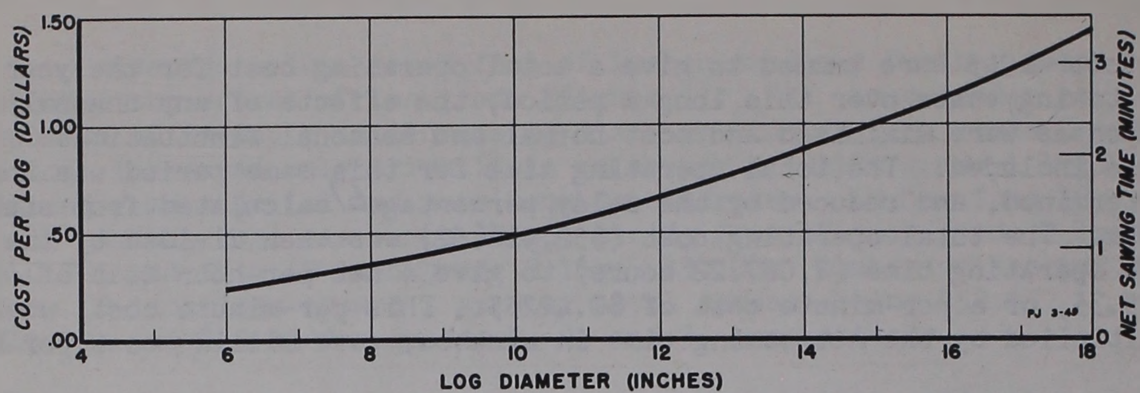[7]/ The time the log was on the carriage excluding delays.

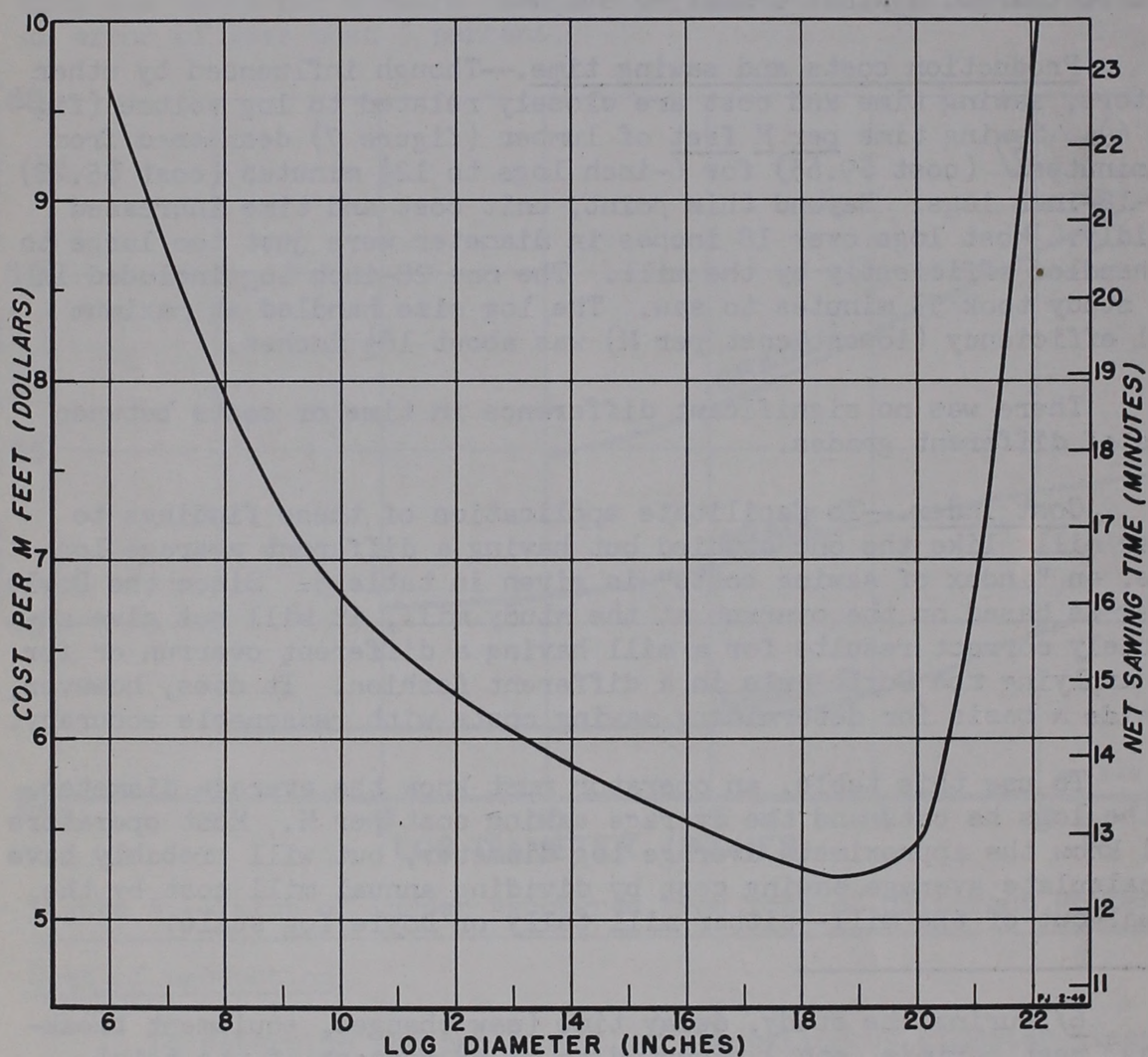Figure 6.--Milling cost and net sawing time per log.

Figure 7.--Milling cost and net sawing time per M feet, mill tally
(average of all log grades).

Table 5.--Sawing cost per M board feet, mill tally and Doyle log scale, in percent of cost of sawing the average-size log

| Log diam. (ins.) | Mill Tally | | | | Doyle Log Scale | | | |
| | Size of average log | | | | Size of average log | | | |
	9 inches	10 inches	11 inches	12 inches	9 inches	10 inches	11 inches	12 inches
6	132.5	141.0	147.9	154.1	111.1	131.4	150.4	169.3
7	120.4	128.1	134.4	140.0	137.9	163.1	186.6	210.0
8	108.9	115.9	121.6	126.7	129.4	153.0	175.1	197.1
9	100.0	106.4	111.7	116.3	100.0	118.3	135.3	152.3
10	93.9	100.0	104.9	109.3	84.5	100.0	114.4	128.8
11	89.5	95.3	100.0	104.2	73.9	87.4	100.0	112.6
12	86.0	91.5	96.0	100.0	65.6	77.6	88.8	100.0
13	83.2	88.6	92.9	96.8	59.9	70.8	81.0	91.2
14	80.7	85.9	90.2	93.9	55.6	65.7	75.2	84.6
15	78.4	83.4	87.6	91.2	52.2	61.7	70.6	79.5
16	76.3	81.2	85.2	88.8	49.4	58.4	66.8	75.2
17	74.3	79.1	82.9	86.4	47.2	55.8	63.8	71.8
18	72.5	77.2	81.0	84.3	45.2	53.4	61.1	68.8

By multiplying the average cost per M by the figures in the column closest to the average log diameter, the approximate cost per M for any diameter can be easily calculated. As an example: Suppose a mill has been cutting logs averaging 10 inches at an average cost of $11 per M, Doyle log scale, and the cost of sawing 8-inch logs is desired. Under the 10-inch Doyle column in table 5, opposite 8 inches is found 153. Multiplying the $11 average cost by this index of 153 percent gives $16.83--the cost of sawing 1,000 feet, Doyle scale, of 8-inch logs.

Realization values

Realization value is the "value" of some incomplete product, based on what could be "realized" from it by converting it to end products. Thus, the green-lumber realization value of logs on the sawmill deck (deck to green chain value) is the "value" of these logs that could be "realized" by sawing them into green lumber. Two realization values were calculated in this study: the deck to green chain value, and the stump to green chain value.

Table 6.--Realization value per log--deck to green chain

Diameter (inches)	Grade 1	Grade 2	Grade 3
	- - Dollars - -		
6	...	...	0.60
7	...	...	.89
8	...	1.44	1.18
9	...	1.79	1.49
10	2.50	2.17	1.82
11	2.98	2.61	2.22
12	3.61	3.17	2.71
13	4.40	3.85	3.33
14	5.35	4.68	4.12
15	6.47	5.65	5.05
16	7.75	6.78	6.13
17	9.15	8.05	7.30
18	10.58	9.41	8.50

Deck to green chain.--Deck to green chain realization value is here computed as the difference between total sawmill cost, not including profit or risk allowances, from log deck to green chain and the value of rough, green lumber. It may be considered as the sawmill operator's margin to cover cost of logs at the mill plus profit and risk.

Realization value per log increased rapidly with increase in diameter (table 6). Not only was more lumber produced from the larger logs, but this lumber was worth more per unit and the sawing costs per M were lower. The difference between the three log grades is clear. For example, at 10 inches the realization value of grade 1 logs is $2.50 per log, for grade 2 logs $2.17, and for grade 3 logs $1.82. At 19 inches, the realization values per log for grades 1, 2, and 3 are $11.85, $10.48, and $9.48, respectively.

Realization values per M feet (figure 8) increased by diameter within all log grades because of an increase in lumber value per M and a decrease in milling cost per M. For example, the average realization value per M, mill tally, for 16-inch grade 1 logs was $45.08, while for grade 2 and 3 logs of the same diameter the mill tally realization values per M were $38.30 and $34.25, respectively.

This means that, in general, an operator who could afford to pay $15 per thousand, mill tally, for 16-inch grade 3 logs could actually make more money by paying $25 per thousand, mill tally, for 16-inch grade 1 logs. It is realized that logs are normally purchased by log scale--not by mill tally. But the particular log scale used and its application so affect the realization values through overrun

that presentation of results by log scale was not attempted here. Those who want deck to green chain realization value by log scale can obtain it with reasonable accuracy for their mill through multiplying the results in figure 8 by their own percentage overrun plus 100. One point, however, might be made here: If the overrun is high, the differences in realization value will also be high. For example, if overrun under the Doyle rule for 10-inch logs is 50 percent, then the difference in realization value between grades 1 and 3 will be roughly $7.50 x 150 percent, or $11.25 per M, Doyle log scale.

Stump to green chain.-- Stump to green chain realization values (the margin remaining for stumpage, plus profit and risk for logging, transportation, and milling) may be calculated in several ways, each accurate for a particular sawmilling set-up. One extreme might be represented by a company which owns its own timber and conducts all phases of its logging on an hourly rate basis; the other by a company which buys all logs by Doyle log scale, delivered at the mill yard, or buys stumpage and contracts the logging, both on Doyle log scale. In this latter case, all costs prior to milling can be allocated on a log-scale basis regardless of diameter. Between these two extremes are many variations. No attempt was made to approximate green chain realization values for every possible variation, but the values under the two extremes were calculated.
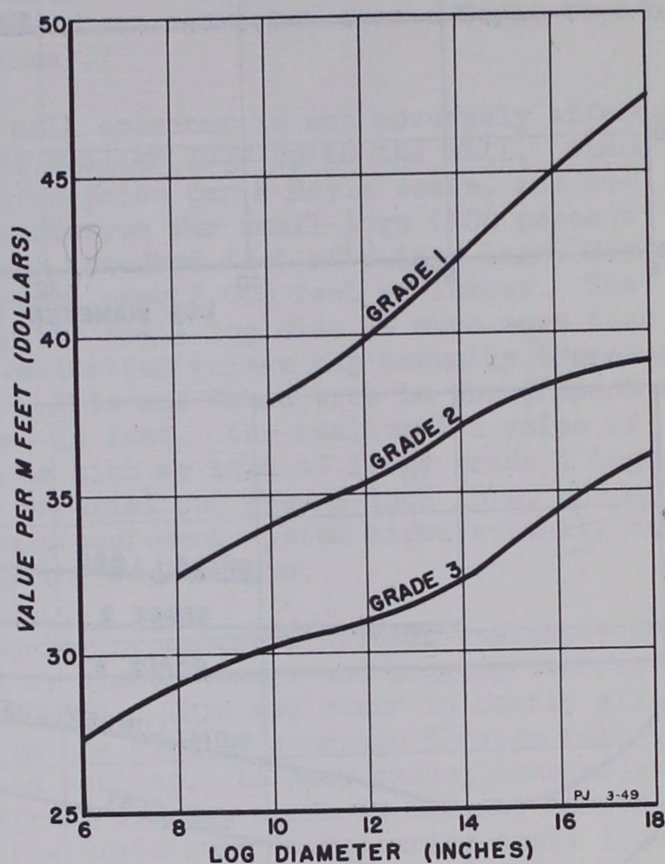

Figure 8.--Log deck to green chain realization values per M feet, mill tally.

FIRST EXAMPLE: In this instance, a company is assumed to own its own timber and conduct all phases of its logging on an hourly rate basis. A mill tally basis for all costs, including stumpage charges, is used to determine realization value. The effect of log grade and size is well demonstrated (figure 9, Top). With such a set-up, with stumpage valued at $20 per M, mill tally, all grade 3 logs below 11 inches in diameter are converted to lumber at a loss. Six-inch grade 3 logs show a net loss of $10.30 per M, mill tally. All grade 2
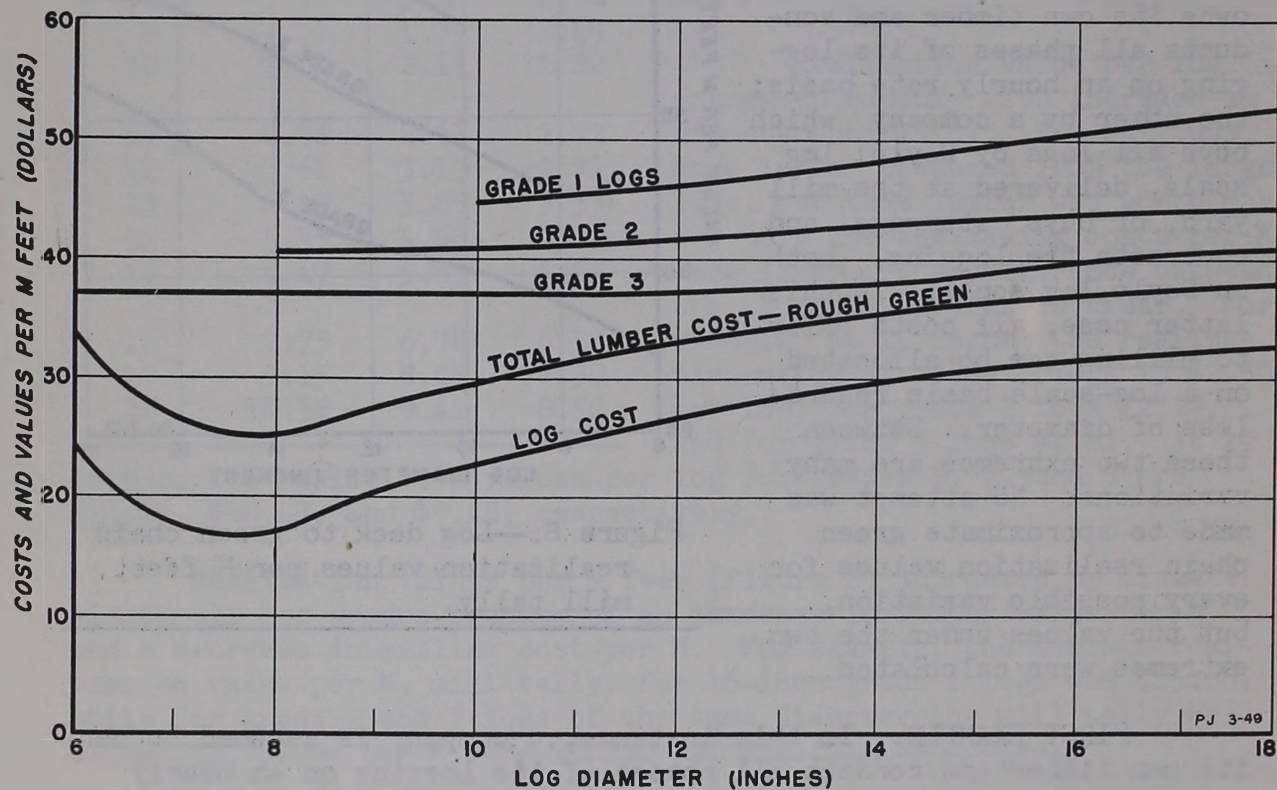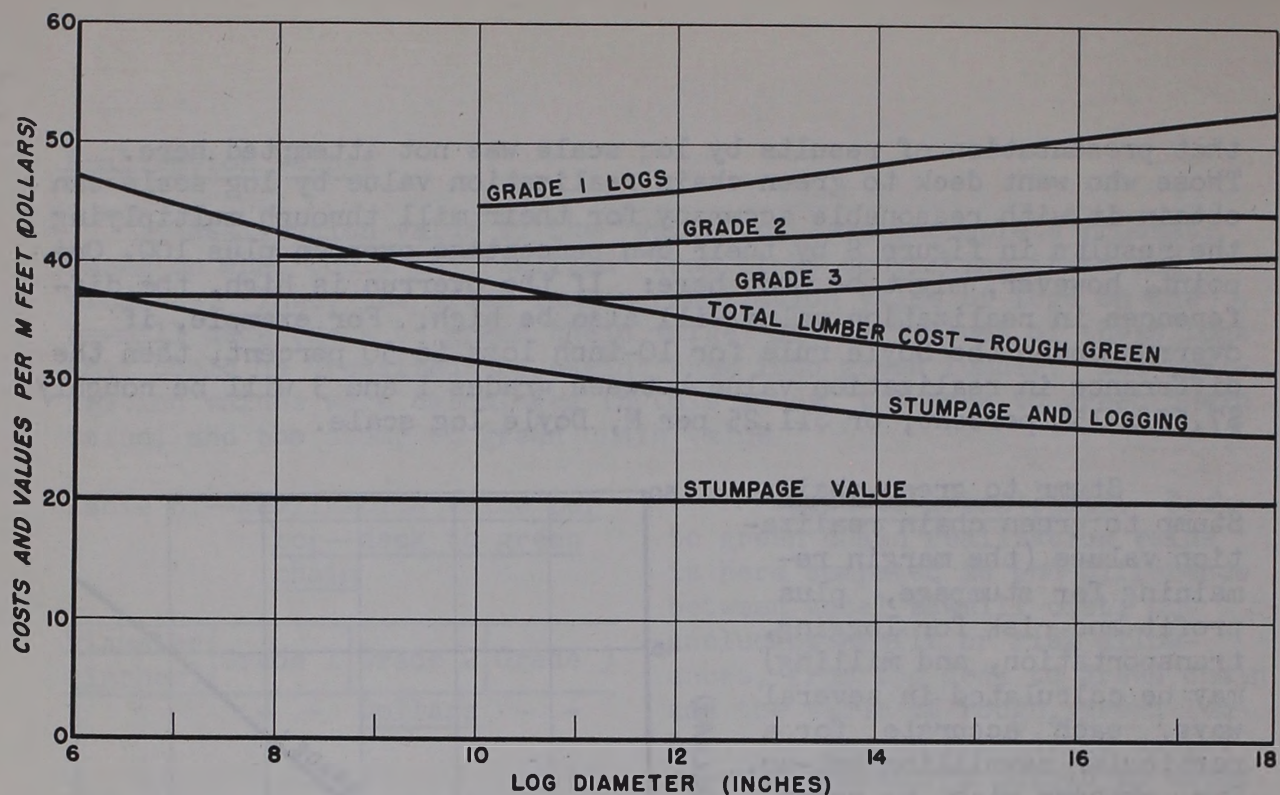
Figure 9.--Production costs and lumber values. Top, Mill owner's
stumpage at $20 per M, mill tally. All costs and values on mill
tally basis. Bottom, Logs purchased for $35 per M, Doyle scale,
delivered at the mill. All costs and values on mill tally basis.

logs above 9 inches in diameter can be profitably converted, while the maximum margin remains from large grade 1 logs. The margin for all grades increases with diameter up to 18 inches.

SECOND EXAMPLE: This illustrates a condition at the opposite end of the scale, and one frequently occurring in East Texas. Here it is assumed that logs are purchased at $35 per M Doyle scale delivered at the mill yard--or stumpage is purchased at $20 per M Doyle scale, and logging is contracted at $15 per M Doyle scale for logs delivered to the mill. To facilitate comparisons between this and the first example, all costs have been converted from a Doyle to a mill tally base (figure 9, Bottom).

In this situation, the mill operator is not adversely affected by the greater cost of handling smaller logs up to the mill, since the logs are purchased at a given price per M Doyle scale, and because this scale gives a large overrun for small logs (104 percent at 8 inches). That is, from each thousand feet of 8-inch logs, Doyle scale, the operator is able to cut over 2,000 feet of lumber. The higher sawing cost entailed by the small log size is much more than offset by this overrun, and realization values may actually increase with decreasing log diameter. This was found true in the present example for grade 2 and 3 logs--in fact, the realization value of 8-inch grade 2 logs is nearly as high as that of large grade 1 logs. Given an unlimited market for material cut from 8-inch logs, the mill owner operating under this log procurement system might actually make maximum profit by cutting only the small sizes.

Comparison of these two log procurement systems indicates how mill owners may be subsidized by timber owners and logging contractors before the logs reach the mill. This may occur in nearly all phases of log procurement--from the sale of stumpage through felling and bucking, to loading and hauling. In many cases, some adjustment in stumpage price or contract logging costs is made to compensate for the deficiencies of the Doyle rule in measuring small logs. But in transactions of this kind the small timber owner and contractor are often at a disadvantage because they are less well informed regarding the true scale, or mill recovery from logs, than the mill operator.
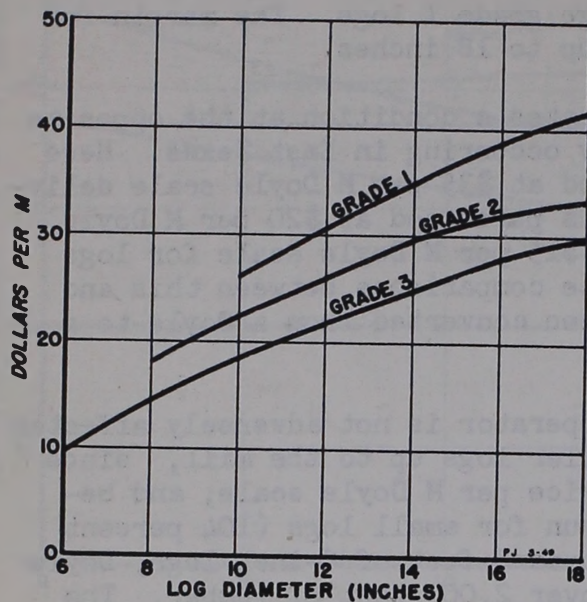
Figure 10.—Margin for stumpage, profit, and risk.

Stumpage values.—The arbitrary valuation of stumpage at $20 per M, mill tally, in the first example, though facilitating comparison between the two extremes, somewhat clouds the picture from the landowner's standpoint. The value of stumpage may be computed as that remaining after all costs of manufacture, including an allowance for profit and risk by each entrepreneur, have been subtracted from the final lumber value. The margin available for stumpage, profit, and risk is shown in figure 10. The rise from $9.60 at 6 inches to $29.75 at 18 inches for grade 3 logs demonstrates the effect of increasing diameter. The difference between log grades is equally apparent.

Summary

A study of shortleaf and loblolly pine log values and milling costs was made to determine the relationship of diameter and log grade to net lumber realization values at medium or small west Gulf mills. The study mill sawed daily about 25,000 feet of logs, Doyle log scale. It was equipped with a 60-inch solid-tooth headsaw, 4-saw edger, 20-foot trimmer, steam shotgun feed, and manual setworks. Logs were turned by hand. A total of 454 logs, ranging from 5 to 27 inches in diameter, were studied. Total mill tally of lumber produced was 50,540 board feet. All logs were graded by the Crossett log grading system.

1. Overrun varied as follows:

   Doyle rule: from 104 percent at 8 inches to 7 percent at 18 inches.

   Net Scribner Decimal C: from 47 percent at 8 inches to 15 percent at 18 inches.

   Net International $\frac{1}{4}$-inch: from 7 percent at 8 inches to 2 percent at 18 inches.

2. Cubic-foot recovery varied from only 54 percent of total log volume at 6 inches up to 73 percent at 18 inches.

3. Lumber grade recovery from logs of each size-grade class was determined. For 16-inch logs, the yield of No. 1 Common and Better

lumber averaged 83 percent of the total yield from grade 1 logs, 58 percent from grade 2, and only 23 percent from grade 3.

4. Net sawing time per M feet varied from 23 minutes for 6-inch logs to 12½ minutes for 18-inch logs. Sawing time and cost per minute of operating time were used as a basis for determining green lumber production costs per log and per M feet. Cost did not vary significantly with log grade, but varied by diameter from $9.65 per M for 6-inch logs down to $5.28 per M for 18-inch logs. Production costs rose excessively for logs over 18 inches in diameter because of physical limitations of the mill.

5. Value per M feet of lumber (rough, green, OPA prices of May 1946) increased in all log grades with increasing diameter. The range in values was:

Grade 1: From $44.65 at 10 inches to $52.65 at 18 inches.

Grade 2: From $40.40 at 8 inches to $44.30 at 18 inches.

Grade 3: From $36.90 at 6 inches to $40.80 at 18 inches.

6. Log deck to green chain realization values--margin for stumpage, logging, profit, and risk--per M feet, mill tally, varied from $27.30 for 6-inch grade 3 logs to $47.40 for 18-inch grade 1 logs. The range by log grades was:

Grade 1: From $37.80 at 10 inches to $47.40 at 18 inches.

Grade 2: From $32.40 at 8 inches to $39.00 at 18 inches.

Grade 3: From $27.30 at 6 inches to $35.80 at 18 inches.

7. Stump to green chain realization values, determined by adapting Crossett study logging costs, varied greatly with different log rules and log procurement systems. At hourly wage rates for all labor and with stumpage valued at $20 per M, mill tally, all grade 3 logs under 11 inches in diameter were converted at a loss, while maximum realization occurred from the large grade 1 logs. For logs purchased at the mill by Doyle log scale, realization value was nearly as high for 8-inch grade 2 logs as for large grade 1 logs.

8. Index curves or tables for logging (see figure 11) and sawing costs (table 5) enable an operator with similar woods and mill equipment and practices to determine the effect of log diameter on costs for his operation--provided his average log diameter and average lumber production cost are obtainable.

Literature Cited

(1) Garver, R. D., and Miller, R. H.
    1933. Selective logging in the shortleaf and loblolly pine
        forests of the Gulf States region. U. S. Dept.
        Agr. Tech. Bul. 375, 54 pp., illus.

(2) Lodewick, J. Elton.
    1941. West Coast log values: 1. Douglas-fir from the Oregon
        Cascades. Pacific Northwest Forest and Range Experi-
        ment Station, Products Paper No. 3. 40 pp.

(3) Rapraeger, E. F.
    1938. Results and application of a logging and milling study
        in the western white pine type of northern Idaho.
        Univ. Idaho Bul. No. 16, Vol. 33, 59 pp., illus.

(4) Reynolds, R. R., Bond, W. E., and Kirkland, Burt P.
    1944. Financial aspects of selective cutting in the manage-
        ment of second-growth pine-hardwood forests west of
        the Mississippi River. U. S. Dept. Agr. Tech. Bul.
        861, 118 pp., illus.

Appendix

Log grading rules used in study

The Crossett log grading rules, as defined by Reynolds, Bond, and Kirkland (4), were used. These rules are:

No. 1: Surface-clear logs 10 inches d.i.b. or over, and logs over 16 inches d.i.b. with not more than three 2- to 4-inch knots; length, 10 feet or over.

No. 2: Logs 8 inches d.i.b. or over containing numerous small knots; or logs more than 14 inches d.i.b. containing four to six 2- to 4-inch knots; length, 10 feet or over.

No. 3: Knotty or crooked merchantable logs 8 inches d.i.b. or over that do not fall in either No. 1 or No. 2 grade; length, 10 feet or over.

No. 4: Logs that are extremely crooked, or less than one-third sound.

According to these rules, grade 4 logs are essentially culls. Such logs are usually left in the woods. Very few grade 4 logs were brought into the study mill and none were included in the study. Merchantability standards for the small or medium-sized circular mill permit sawing of logs smaller than 8 inches d.i.b. For this reason, the 8-inch diameter limit in grade 3 logs was ignored during the present study.

Application of the log grades.--The log grades used are quite simple but require some judgment in their application. Distribution of knots, as well as number and size, should be considered. For example, a log over 16 inches d.i.b. would be classed as grade 1 even though it contained more than three 2- to 4-inch knots--provided they were all within a foot or so of the end of the log. Similarly, a log 14 inches or larger containing over six 2- to 4-inch knots would be classed as grade 2 if the knots were bunched or if they all occurred on one face.

In general, scaling defects do not affect the grade of a log. This is logical since they reduce the volume, not the quality, of the lumber produced. When defect becomes so serious that the quality of the remaining volume is affected, however, it does influence the log grade assigned. The following standards with respect to defect were followed in grading the study logs:

Sweep that reduced log volume but did not reduce percent of grade recovery was not considered in applying the grading rules.

Rot in logs, if affecting one-third or more of the log volume, automatically reduced the log one grade below that indicated by the surface characteristics.

Fire scar was not considered a defect unless over one-third of the log volume was affected. Logs with more than one-third of the volume involved in the scar were automatically reduced one grade below that indicated by the other surface characteristics.

Adaptation of logging costs

To obtain realization values covering all steps from stump to green chain, it was necessary to adapt logging costs from other studies. Crossett study data were used because logging conditions, equipment, and methods closely matched current East Texas conditions. The Crossett logging costs per M for logs in each diameter class, based on gross International ¼-inch rule, were converted to an East Texas mill tally basis by using the East Texas overrun of the gross International rule. This gave logging costs per M by log diameters on a mill tally basis accurate for the time at which the Crossett study was made.

The costs were brought up to date through use of index curves. These curves are based on the premise that though actual costs may have changed greatly, the relationship between logging costs and log diameters has remained reasonably constant (assuming similar logging conditions, methods, and equipment). The curves are constructed by setting the logging cost for some particular log diameter as 100 percent, then calculating the cost for other diameters as a percent of the selected one. From these curves, if the average logging cost per M for any log diameter is known, the costs per M for all other diameters can be calculated.

In East Texas, the pine logs now being sawed average about 11 inches in diameter inside bark (volume of about 60 feet, Doyle scale), and the average logging cost runs about $15 per M, Doyle scale. With these facts at hand, and the Crossett logging costs converted to the East Texas mill tally basis, we were able to adapt the Crossett costs through the following steps:

1. Mill tally logging costs were converted to a Doyle basis by using the East Texas Doyle overrun figures.

2. Index curves were constructed from these converted logging costs--one for mill tally, the other for Doyle--using the cost of 11-inch logs as a base.

3. Logging costs per M feet Doyle were then obtained by multiplying these index figures by $15--the estimated present-day cost of logging in East Texas.

4. Similarly, logging costs by diameters on a mill tally basis were obtained by multiplying the mill tally cost index figures by $10.58--the estimated cost converted to a mill tally base.

Since the Crossett study included no logs less than 8 inches in diameter, it was necessary to extend these data. These extended values are shown in figure 11.

Factors affecting overrun

The more important of the factors affecting overrun or underrun are discussed below.

Reducing kerf and cutting thicker materials.--Both the Scribner Decimal C and International $\frac{1}{4}$-inch log rules are based on a $\frac{1}{4}$-inch saw kerf. The saw kerf at the study mill was 5/16 inch. Overrun, therefore, was decreased because of the extra 1/16-inch kerf.

An analysis of the distribution of the lumber cut by thicknesses was also made. The increase found in the proportion of 1-inch lumber cut from the large diameters reflects the common practice of cutting large logs for grade. Large smooth logs, even though dense, will yield the highest value when cut into finish grades of lumber. This practice, together with that of cutting small logs into dimension, further increases the overrun of the small diameters, since both the Scribner and International rules are based on yields of 1-inch boards.

To determine roughly the effect of these two factors on overrun by log scale, an adjustment was made on the net scale by Scribner and International log rules. To adjust for kerf, the log scale was reduced by 0.045 percent--the difference between the International $\frac{1}{4}$-inch and 5/16-inch rules. The overrun from this adjusted scale is, of course, higher than from the normal scale (figures 12 and 13).

The adjusted log scale was next increased according to the amount of lumber cut in each thickness class. Though somewhat arbitrary, the following percentages represent approximately the savings due to thicknesses cut:

4-inch lumber	20 percent was added to log scale;
3-inch lumber	18 percent was added to log scale;
2-inch lumber	13 percent was added to log scale.

The overrun resulting from this adjusted (figures 12 and 13) log scale is believed to be a fair approximation of the overrun that might be expected if a $\frac{1}{4}$-inch kerf had been cut and only 1-inch lumber produced.
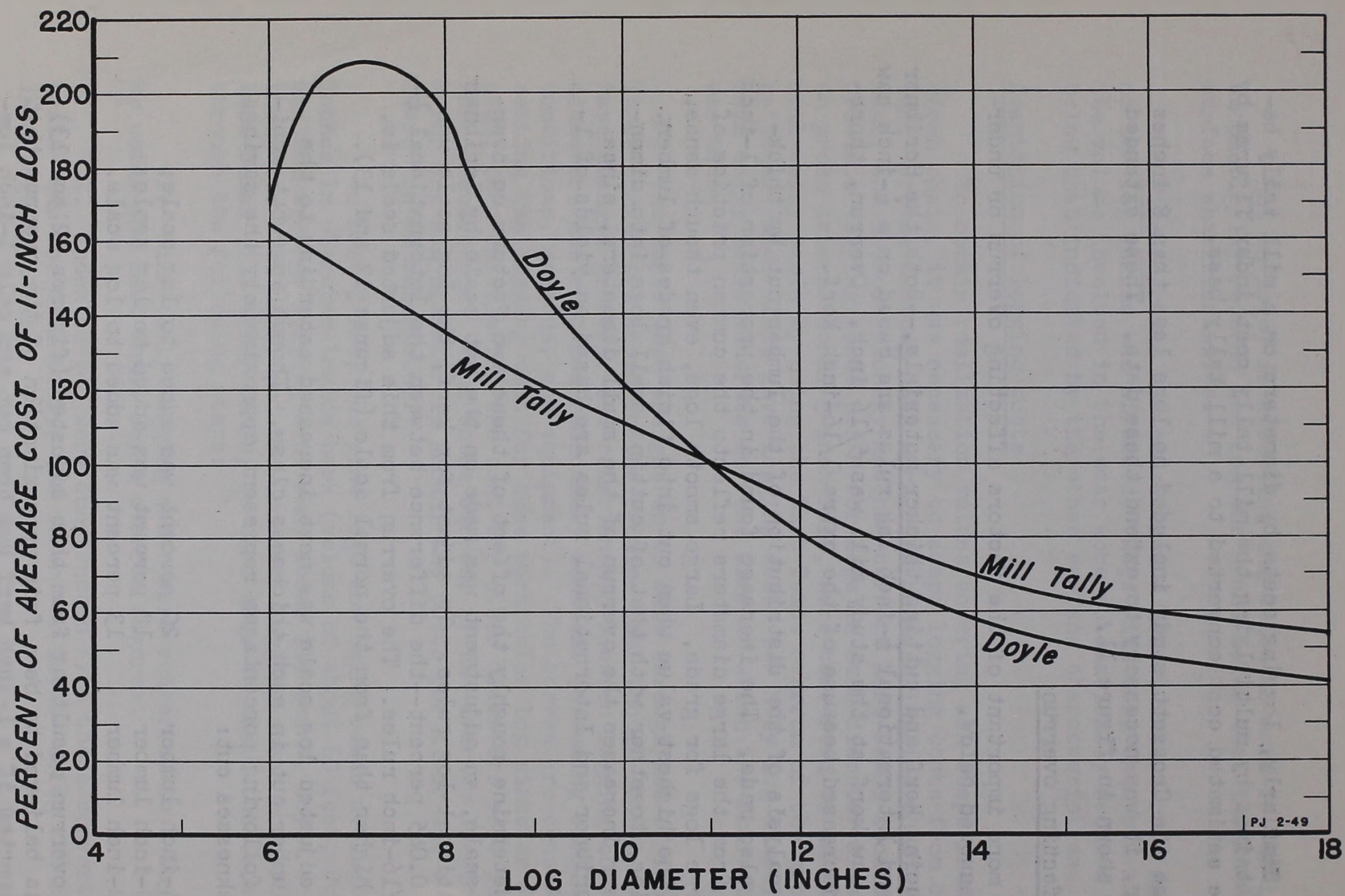
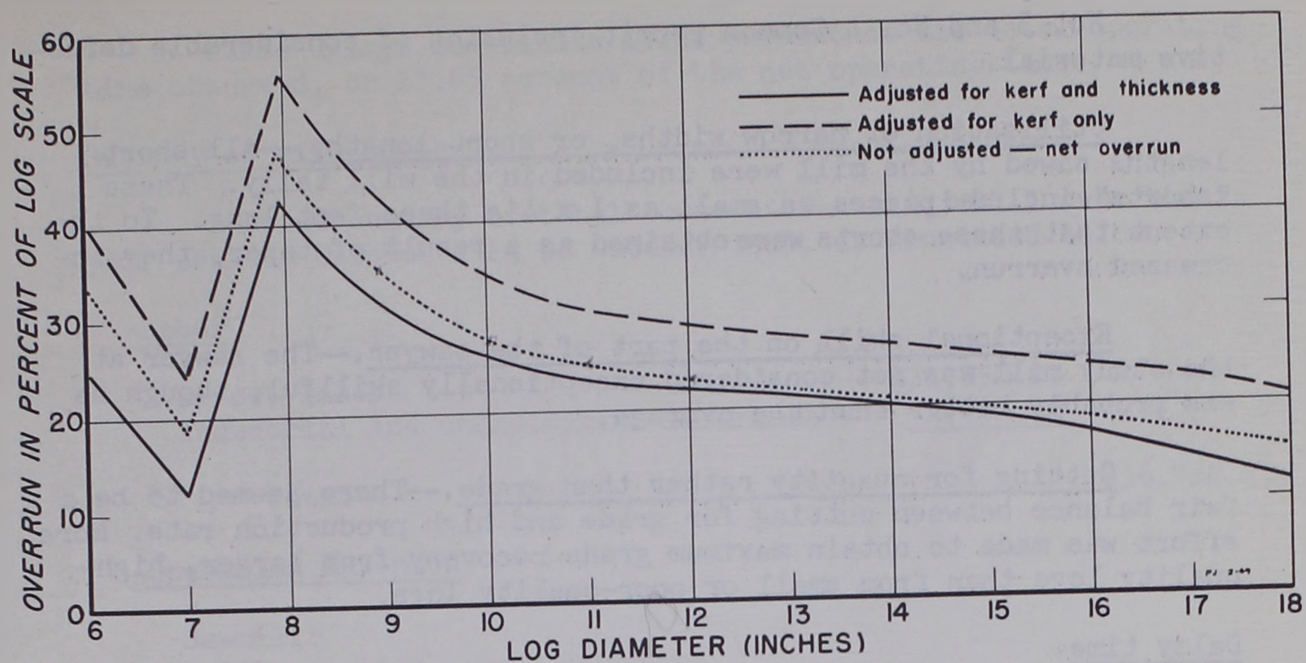Figure 11.--Index curves of logging costs--Doyle rule and mill tally.

Figure 12.--Overrun from Scribner Decimal C log rule, showing adjustments for kerf and thicknesses cut.

Cutting scant thicknesses.--Thickness of the lumber cut was checked on the green chain throughout the study. It was fully up to, or perhaps slightly above, the thickness standards for rough, green lumber set by the Southern Pine Inspection Bureau.

Utilization of lumber grades which admit unsound material.--
All lumber was graded under Southern Pine Inspection Bureau grade rules. The following grades were recognized:

B and Better   No. 4 Common
C   Dense Select Structural
No. 1 Common and Dimension   Dense Structural
No. 2 Common and Dimension   No. 1 Dense
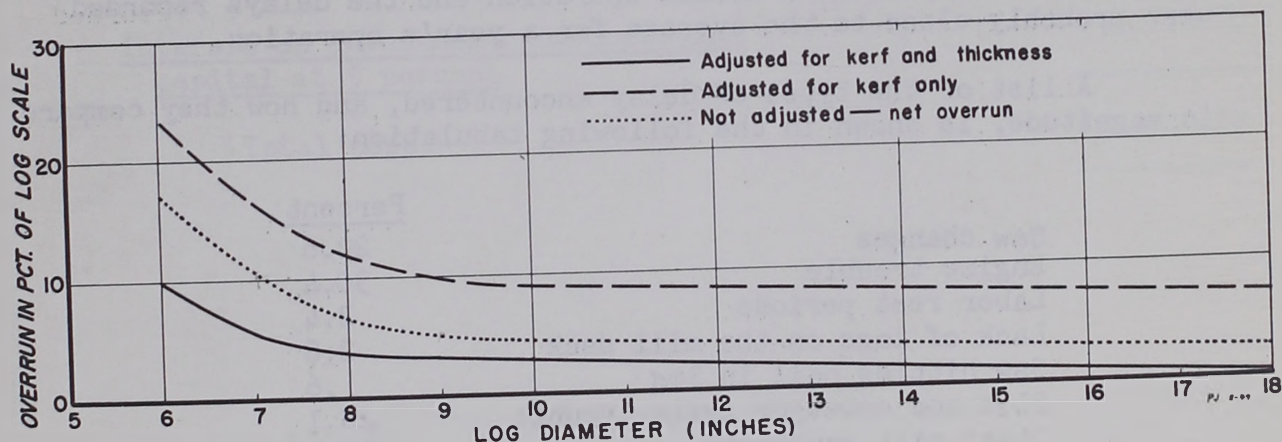No. 3 Common and Dimension   No. 2 Dense (1050 F).

Figure 13.--Overrun from International 1/4-inch log rule, showing adjustments for kerf and thicknesses cut.

No. 3 and No. 4 Common permit inclusion of considerable defective material.

Utilization of narrow widths, or short lengths.--All short
lengths sawed by the mill were included in the mill tally. These
"shorts" included pieces as small as 1 x 4's three feet long. To the
extent that these shorts were obtained as a result of taper, they in-
creased overrun.

Exceptional skill on the part of the sawyer.--The sawyer at
the study mill was not considered exceptionally skillful, though he
was probably better than the average.

Cutting for quantity rather than grade.--There seemed to be a
fair balance between cutting for grade and high production rate. More
effort was made to obtain maximum grade recovery from larger, high-
quality logs than from small or poor-quality logs.

Delay time

Rather than charge each delay to the log on the carriage at
the time, a complete record of all delay time was kept. This time
was prorated according to the net headsaw time of any log or log
group. Thus each log bears a share of the delay time proportional
to its net sawing time.

The delays observed during the short study period are not nec-
essarily representative of average mill operation, and delay time will
vary considerably among mills. In the Crossett study, the delay, or
ineffective, time was found to be 6.76 percent of the total time (4)
while Lodewick, studying Douglas-fir log values in 1941, found a de-
lay time of 12.6 percent (2). Both of these operations were in rela-
tively large band mills, and the Crossett study was conducted before
the war when mill equipment could be better maintained and labor was
perhaps more efficient. These factors probably account for most of
the differences observed. In the opinion of the mill manager, the
study covered a period of normal operation and the delays recorded
were probably close to the average for a year's operation.

A list of the types of delay encountered, and how they compare
in magnitude, is shown in the following tabulation:

	Percent
Saw changes	22.6
Engine trouble	30.4
Labor rest periods	2.4
Lack of logs on the mill deck	2.8
Saw hitting nail in log	.6
Slab and conveyor chain trouble	28.1
Other mill equipment	13.1
Total	100.0

These delays constitute 13.68 percent of the total operating time observed, or 15.85 percent of the net operating time.

Summary of mill costs

A brief summary of total costs at the study mill over the 1-year period, October 1944 to October 1945, is presented below.

Labor

Direct labor	$34,650.07	
Industrial and unemployment insurance	2,134.16	
Total		$36,784.23

Operating Expenses

Sawmill:		
Oil supplies, small supplies, and repairs	$ 3,361.08	
Office:		
Supplies and salaries	5,021.35	
Utilities:		
Gas, electricity, water, telephone, and telegraph	1,454.16	
Professional services:		
Banking, auditing, and attorney	625.43	
Total operating expenses		$10,462.02
Taxes (State, county, city, and school)		204.50
Fire insurance		1,172.50
Depreciation on mill, office equipment, and furniture		2,543.57
Interest on investment and operating capital at 5 percent		1,750.00
Total cost		$52,916.82